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THE RELATION OF WATER-RAKING TO THE KEEPING QUALITY OF CRANBERRIES.

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METHODS OF HARVESTING CRANBERRIES.

THE GREATER PART of the cranberry crop of the United States is harvested dry, being either picked by hand or gathered by scoops or rakes of various designs. Most growers, indeed, take great care not to allow the berries to be picked when wet with dew. The practice of water-raking—that is, of flooding the bog and raking off the berries as they float on or near the surface of the water—has, however, developed to some extent in Wisconsin and has given rise to so much discussion as to its effect on the keeping quality of the fruit that the question has been made the subject of a special investigation by the writers.

The present bulletin, which deals with the water-raking problem only in its relation to the keeping quality of the fruit, is based on investigational work in Wisconsin extending over three seasons. In 1918 a general study was made of harvesting methods and conditions throughout the cranberry regions of the State, and Wisconsin berries were followed through the storage season in the markets of Minneapolis and Chicago. In 1919 attention was confined chiefly to a

study of the flooding waters in various parts of the State. In 1920 careful comparative shipping and storage tests were made of berries harvested in various ways.

The investigation of water-raking has been confined to the State of Wisconsin, because this method of harvesting cranberries is practiced nowhere else. Indeed, it is doubtful whether it would be practicable elsewhere, even if desirable. To bring about its introduction on the large bogs of Massachusetts and New Jersey such extensive alterations would be necessary as to make it out of the question unless the practice could be proved to be extraordinarily beneficial.

STORAGE CONDITIONS.

Aside from the action of insects or actual crushing, cranberries in storage spoil chiefly from decay caused by fungi or from smothering. These causes of spoilage and some of the factors which influence them have been discussed in several papers (4, 5, 6, and 9).[1] It is obvious that those conditions which have been proved injurious to the keeping quality of dry-raked cranberries will also be injurious, perhaps even more seriously so, to water-raked berries. Careful handling, low temperatures, and good ventilation will improve the keeping quality of water-raked cranberries as of cranberries harvested in other ways.

A striking example of the importance of good ventilation in the storage of water-raked cranberries was observed at Minneapolis in 1918. Here water-raked cranberries of the same variety (Searls), from the same marsh, and handled in the same way were stored in picking boxes and in barrels. On December 9, 1918, the average condition of typical samples showed 22 per cent of spoiled berries in the lot stored in boxes and 34 per cent in those in barrels.

It is obvious and must be constantly borne in mind in considering the material presented in this bulletin that the results here reported can not be expected to apply to all cranberry conditions. Too many variable factors are involved to make it possible to duplicate exactly conditions or results. The variation in the kinds and quantity of fungi present on different bogs and even in different seasons on the same bog has been frequently remarked. Different varieties of cranberries are known to have quite different keeping qualities and may well be differently affected by water-raking. Different water and climatic conditions would undoubtedly have an important effect on the results. To mention only two examples: One could not expect water-raked berries to dry so quickly in the generally humid atmosphere of the cranberry regions of Washington and Oregon as in the much drier air of Wisconsin, and the relatively warm flooding water

[1] The serial numbers in parentheses refer to "Literature cited" at the end of this bulletin.

of New Jersey would have a different effect on the berries than the much cooler water of Wisconsin. The results of the experiments here described will be useful even to Wisconsin growers only when considered in connection with the conditions on their own marshes and with their previous experience.

PRESENT PRACTICE IN WATER-RAKING.

The usual practice in water-raking is to flood the vines so that the cranberries float on or near the surface. They are then harvested with rakes much like those used in dry-raking, but usually somewhat larger and with the teeth longer and farther apart. After the berries are harvested they are dried as soon as practicable, usually by pouring them into specially made drying crates, which are then piled and an empty crate placed on top of the pile to protect the berries from the sun. A common type of crate is 24 by 24 inches in size by 6 inches deep, with the bottom and two sides made of laths spaced to permit the free circulation of air. The crates are usually filled one-fourth to one-third full, and an open space is left in the middle to increase the ventilation. When the berries are dry they are removed to the storehouse. A few growers with large and well-ventilated storehouses follow the practice of taking the berries directly into the storehouse after they are raked from the water and placing them in shallow crates, which are so piled as to permit the free circulation of air.

If there is injury to berries from water-raking it probably arises either from their submergence or in the process of drying. Several important factors in each of these processes will be briefly considered.

IMPORTANT FACTORS IN DRYING CRANBERRIES.

The universal experience of cranberry growers agrees with the results of experiments conducted in Massachusetts and in Maine in indicating that it is injurious for cranberries to remain damp for a long time in storage (6, p. 122, and 9, p. 9). It is therefore to be expected that, other things being equal, the more quickly berries are dried after being water-raked the better. The time required for drying will depend, first of all, upon the weather and, second, upon the way they are handled. The most favorable conditions for drying are obviously a good breeze and a low humidity, conditions which apparently are somewhat more frequent in Wisconsin (3) than in other cranberry regions.

The weather conditions are, of course, beyond the growers' control. The rate of drying, however, is directly influenced by the manner in which the cranberries are handled. Berries will dry much more quickly if the drying crates are not filled too full, the grass and

leaves carefully removed, and the crates piled in a favorable location. It goes without saying that the more quickly the berries are placed in the drying crates after they are harvested the better. It is important, too, that they be handled as carefully as possible to avoid bruising, for even slight injuries have been shown to increase decay (9, p. 13). In this respect there is some advantage in placing the berries directly in the crates in which they are to be stored.

INJURY DURING SUBMERGENCE.

That cranberries are injured and may be wholly spoiled by long-continued submergence is well known (9, p. 5, and 6, p. 117). The extent of the injury which will occur in a given time is governed by various factors, among which are the age of the berries, the temperature of the water, and the oxygen content of the water. It is highly probable that the variety of the berry and the fungi present may influence the amount of injury, though no definite statements on this point are possible at present.

AGE OF THE BERRY AT THE TIME OF SUBMERGENCE.

In general, any factor which influences the oxygen requirement of the cranberry affects the extent of the injury due to smothering. Green berries respire more rapidly than ripe ones, and green berries are therefore the first to suffer from smothering when flooded. (See also 6, p. 118.) This is well shown by the relative percentage of spoilage in green (not fully colored) and ripe (fully colored) water-raked berries examined at Chicago and Minneapolis in 1918, as shown in Table I.

TABLE I.—*Keeping quality of green and ripe water-raked cranberries grown on the same bog in Wisconsin in 1918.*

Variety.	Where examined.	Date examined.	Spoiled berries (per cent).	
			Green.	Ripe.
Metallic Bell	Chicago, Ill.	Oct. 27	7	7
Do	do	Dec. 7	48	32
Searls	Minneapolis, Minn.	Dec. 9	54	34

In the case of the Metallic Bell variety the first counts were made when the barrels arrived at Chicago, and the second were from the same barrels about six weeks later. The two lots of the Searls variety examined were stored in barrels under the same conditions. The green berries were under water at the time of flooding not more than two and a half days, while the late-picked berries were in the water for three to five days. Notwithstanding this fact, the late-

picked berries show better keeping quality than those picked early. The greater injury to the light-colored early-picked berries is apparently due to the higher respiration rate of these berries.

TEMPERATURE OF THE WATER.

The effect of temperature is very important in determining the rate of respiration. Morse (8) has recently proved that in the cranberry, as in many other fruits (7), the rate of respiration is twice as rapid at 10° as at 1° C. and that the rate doubles again at 20° C. This means that the amount of oxygen necessary to maintain the normal activity of the berries is twice as great at 10° and four times as great at 20° as at 1° C. On the other hand, the capacity of water for holding oxygen diminishes with the rise of temperature. Other things being equal, then, the colder the water the better it is for use in water-raking. It is obvious that in this respect the conditions are more favorable for continued flooding in Wisconsin than in Massachusetts or New Jersey.

OXYGEN CONTENT OF THE WATER.

The importance of the flooding water in the cranberry industry has led to a careful study of different water supplies and their relation to injury from flooding by one of the writers (Bergman). These studies, which are in part unpublished, indicate that a very important factor, perhaps the most important factor in water injury, is the oxygen content of the water. Water having a high oxygen content will cause much less injury in a given time than that having a low oxygen content. The oxygen content of flooding water under natural conditions is determined by atmospheric pressure, temperature, the quantity of organic matter in the water and substratum, and the light intensity.

As atmospheric pressure varies only slightly from day to day, this factor may for practical purposes be disregarded. The temperature influences both the capacity of the water to hold oxygen and the rate at which the oxygen is taken up from the water by organic matter. Water reaches its greatest capacity for oxygen at 0° C. This capacity decreases with the rise of temperature. On the other hand, the rate of oxidation of organic matter increases with the rise of temperature. From both points of view, then, the cooler the water the more favorable for a high oxygen content.

The presence of decaying organic matter in the water or in the substratum reduces the oxygen content of the water. Decay is a process of oxidation, and decaying organic matter in the water or the substratum can obtain oxygen only from the water. Therefore, it decreases the oxygen content of the water in proportion to the amount of organic matter present and the rate of oxidation, which, in turn, depends on the temperature.

In this connection the source from which the water is drawn or the character of the soil in the reservoir is important. The water of a lake with a muck bottom and swampy margin has generally a lower oxygen content than one with a sand or gravel bottom. The studies of Birge and Juday (2) show that this applies to Wisconsin lakes and the studies of one of the writers (Bergman) have shown that the oxygen content of water from cedar-swamp reservoirs in Massachusetts was only 10 to 40 per cent of that in clear pond water at the same time. For the same reason, the water of reservoirs constructed on marshes is usually low in oxygen content.

The influence of light intensity on the oxygen content of flooding water and its relation to the water injury of submerged cranberry plants has been considered in another paper (1). Briefly, it may be stated that whereas the process of respiration, in which oxygen is taken up from the water by the submerged plant, goes on both in light and in darkness, the process of photosynthesis, in which oxygen is given off to the water by the plant, can take place only in the light. On a clear day the oxygen content of the water on a flooded cranberry marsh in growing condition increases. On the other hand, at night or in cloudy weather the oxygen content of the water is reduced, and if the cloudiness persists for two or three days the oxygen content may become very low and injury may result.

OXYGEN CONTENT OF WATERS USED IN FLOODING CRANBERRY MARSHES IN WISCONSIN.

During September of the years 1918 and 1919 determinations of the oxygen content of more than 130 samples of water from various marshes in Wisconsin were made. Winkler's titrimetric method for determining the oxygen content of water (10, p. 2843) was used in all cases.

From these analyses, of which Table II gives a few typical examples, it is evident that the oxygen content of the flooding water of Wisconsin cranberry marshes is generally below saturation. In some cases the deficiency is very marked. This is due to the fact that in practically all cases the water is held in reservoirs constructed on marshes.

These analyses show that the oxygen content of water in reservoirs and on the flooding sections of marshes increases during the day and that the increase is greater on clear days than on cloudy ones. This is illustrated by the analyses of reservoir water at Black River Falls on September 10 and 11, 1919. On September 10, a cloudy day, the oxygen content of the water at the north end of the reservoir increased from 3.22 c. c. per liter at 11.30 a. m. to 3.74 c. c. per liter at 4.45 p. m. On September 11, a clear day, the oxygen content of the

water at the same station increased from 2.85 c. c. at 10.15 a. m. to 4.28 c. c. per liter at 4.30 p. m.

TABLE II.—*Oxygen content of the water at various hours of the day in the reservoirs of cranberry marshes in Wisconsin.*

Locality.	Date.	Hour.	Temperature (° C.).	Weather.	Oxygen per liter (c. c.).	Approximate saturation (per cent).
	1918.					
Cranmoor	Sept. 25	9 a. m.	13	Clear	5.58	77
Do	do	10 a. m.	13	do	5.77	80
Walker	Sept. 26	11.30 a. m.	15	do	6.92	98
Black River Falls	Sept. 27	10 a. m.	15	Cloudy	4.41	64
Beaver Brook	Sept. 29	11 a. m.	10	Clear	5.11	74
	1919.					
Do	Sept. 6	11 a. m.	15	do	5.19	75
Black River Falls	Sept. 10	11.30 a. m.	15	Cloudy	2.93	42
Phillips	Sept. 16	2 p. m.	15	Clear	3.74	54
Cranmoor	Sept. 19	2 p. m.	15	Cloudy	4.52	65
Walker	Sept. 20	11.45 a. m.	17	Clear	2.22	33
Beaver Brook	Sept. 6	11 a. m.	15	do	5.19	75
		4.25 p. m.	14	Cloudy	5.9	86
Do	Sept. 8	7.45 a. m.	15	Clear	5.03	72
		3.40 p. m.	15	Cloudy	6.00	86
Black River Falls	Sept. 10	11.30 a. m.	15	do	3.22	46
		4.45 p. m.	15	do	3.74	53
Do	Sept. 11	10.15 a. m.	15	Clear	2.85	41
		4.30 p. m.	17	do	4.28	64

The difference in the oxygen content of the water on a clear day as compared with a cloudy one is not as great in this case as in many instances observed in Massachusetts. This is due, no doubt, to the lower temperatures and poorer illumination in the case of the Wisconsin waters, as these were examined in September, while those in Massachusetts were examined in summer.

The increase in the oxygen content of flooding water during the day, as explained in other papers by one of the writers (Bergman), is due to the photosynthetic activity of algæ and other aquatic plants in the reservoir. This activity must necessarily be less in the cool and relatively darker days of September than in midsummer.

EXPERIMENTAL TESTS OF THE KEEPING QUALITY OF WATER-RAKED CRANBERRIES.

The observations of the writers in the markets during 1918 indicated that water-raked berries often show poorer keeping quality than dry-raked or dry-picked berries from the same marsh. Table III gives typical examples of the differences frequently observed.

Figures such as those given in Table III, while suggestive, are open to criticism, since the lots were not in all cases strictly comparable, having come from different places in the bog, and the water-raked berries were not harvested under the best possible conditions. Some of the Searls variety, on which the report is made, for example, were under water from three to five days.

TABLE III.—*Keeping quality of cranberries of the same variety harvested by the wet and dry methods from the same marsh, commercially handled, in 1918.*

Variety.	Where examined.	Date examined.	Spoiled berries (per cent).		
			Water-raked.	Dry-raked.	Dry-picked.
Metallic Bell	Chicago, Ill	Nov. 27	20	8	.....
Do	do	Dec. 3	14	8	.....
Do	do	Dec. 7	32	11	.....
Searls	Minneapolis, Minn.	Dec. 9, 10, and 11	22	.....	10

To furnish a basis for a comparison more accurate than that shown in Table III, a special effort was made in 1920 to obtain a fair comparison of dry-raked and dry-picked cranberries with water-raked berries handled in different ways. The berries used in the various comparative tests were of the same variety and were gathered from the same sections of the marsh. The harvesting, drying, storing, and packing were all done under the close observation of one of the writers, and careful note was taken of the length of time the berries were submerged and the time occupied by the various lots in drying.

Because of the importance of weather conditions in drying water-raked cranberries, the weather data for the period during which the harvesting tests were carried on are presented in Table IV. These data were taken with standard instruments of the United States Weather Bureau by the local observer, Mr. C. L. Lewis, jr.

TABLE IV.—*Weather data at Beaver Brook, Wis., from September 14 to October 2, 1920.*

Date.	Temperature (° F.).		Precipitation (inches).	Frost.	Date.	Temperature (° F.).		Precipitation (inches).	Frost.
	Maximum.	Minimum.				Maximum.	Minimum.		
September 14	84	60	.....		September 23	75	63	0.10	
September 15	77	45	.....		September 24	74	50	.....	
September 16	74	48	.....		September 25	86	56	.01	
September 17	86	47	.....		September 26	72	38	.....	
September 18	76	41	1.13		September 27	70	40	.....	
September 19	54	42	.03		September 28	53	32	.....	Light.
September 20	70	51	.23		September 29	48	28	.02	Heavy.
September 21	79	54	.....		September 30	52	23	.....	Do.
September 22	81	63	.....		October 1	60	28	.....	Do.

Up to September 18 the weather was particularly favorable for drying water-raked berries. Not only was it warm and dry, but there was a strong wind. Wet berries placed in the drying crates at 10 a. m. were dry to the touch at 5 p. m. It is, then, not surprising that under these conditions the best results were obtained.

Most of the experiments were made with berries from the marsh at Beaver Brook, Wis. This locality is especially favorable for the work,

since the marsh has considerable acreages of a single variety, water-raking is regularly practiced, and both barrels and half-barrel boxes were available for the shipping tests. In all, 21 experimental lots, including 76 boxes and barrels, were prepared, shipped to three different markets, and examined at intervals from October 30, 1920, to February 3, 1921. The results of these experiments are summarized in Tables V and VI.

TABLE V.—*Average keeping quality of cranberries (Searls variety) harvested in various ways.*

Date examined.	Spoiled berries (per cent).			
			Water-raked.	
	Hand-picked.	Dry-raked.	Dried Sept. 14–17.	Dried Sept. 25 to Oct. 1.
November 4–6, 1920	5.0	2	4.8	10.6
November 22–24, 1920	8.3	3	8.4	17.0
December 14, 1920	15.2	.....	16.0	.....
January 4, 1921	.....	8	16.5	.....

The figures given in Table V [2] are in all cases the averages of several lots and include among the water-raked cranberries only those which were dried as promptly as possible under the prevailing weather conditions. The results indicate clearly the importance of prompt drying. The water-raked berries dried during the very favorable weather of September 14 to 17 showed practically the same keeping quality as the hand-picked berries, though not so good as the dry-raked fruit, while those harvested during the less favorable weather were distinctly inferior.

The effect of rapid drying is shown in still another way. Ten tests were made in which several boxes of water-raked berries were separated into two lots, one lot being carefully placed in the drying crates so as to permit rapid drying, while the other lot was put in the drying crates rather carelessly, the crates being filled about half full and the berries not separated in the middle of the crate. When the various lots were examined early in November the carelessly dried berries showed 14 per cent more rotten berries than those well dried. This difference (9.6 per cent of the total carelessly dried berries as compared with 8.4 per cent of the carefully dried berries) amounted

[2] The superior keeping quality of the dry-raked cranberries, as compared with the hand-picked berries, is probably due, at least in part, to the slight bruising which berries often suffer in hand-picking. The importance of these slight bruises has been shown in other experiments (9, p. 13), and large berries seem to be more easily injured by hand-picking than smaller ones, as was shown by comparative tests of hand-picking and dry-raking made in New Jersey in 1916, on the Early Black, Howe, and Centennial varieties. In almost all tests dry-raked cranberries have kept somewhat better than those hand-picked (9, p. 14, and 5, p. 198). On the other hand, in dry-raking, a considerable number of berries are lost.

to 1.2 per cent of the volume of either lot of the berries in the test. If the difference seems small, it should be remembered that the lots were identical and their treatment the same, except that they were placed in the drying crates somewhat differently. Moreover, during the early part of the test, the weather conditions were so favorable for drying that even the carelessly handled lots dried very quickly.

The injury resulting from permitting cranberries to remain wet after picking is more clearly shown by two tests in which the berries were kept wet for several days. In the first test one lot of berries was dried as soon as possible after harvesting; a second lot from the same section harvested on the same day (September 17, 1920) was kept wet over night, then dried in good condition; a third lot from this section was kept wet for three days. The third lot showed more than three times as many rotten berries as the first. A similar test was carried out the following week. Three lots of berries harvested on September 25 from the same section were handled as follows: One lot was dried as soon as possible, the second lot was permitted to remain wet in the picking crates over night, and the third lot was left in the picking crates for two days. In this test, as in the previous one, the lot which remained wet for the longest time showed markedly inferior keeping quality. The results of these tests are given in Table VI.

TABLE VI.—*Average keeping quality of cranberries from the same section, treated in different ways after water-raking.*

Treatment.	Spoiled berries (per cent).	
	Nov. 5–6, 1920.	Dec. 14, 1920.
Lot 1, September 17:		
Dried as soon as possible	4.5	16.0
Kept wet over night	11.9	21.7
Kept wet three days	15.8	.....
Lot 2, September 25:		
Dried as soon as possible	10.0	.....
Kept wet over night	11.0	.....
Kept wet two days	15.0	.....

Long-distance shipments, to Washington, D. C., and to San Jose, Calif., of commercially handled water-raked and hand-picked berries from Beaver Brook, Wis., gave somewhat conflicting results, but in general confirmed the results of the more careful tests that under the conditions in 1920 there was very little difference in keeping quality between hand-picked berries and those which had been water-raked and dried under favorable conditions.

One comparative test of hand-picked and water-raked berries was made in which the water-raked berries were dried in the storehouse. In this case the water-raked berries showed inferior keeping quality,

having about one-third more rotten berries than those which were hand-picked. A single test does not furnish a sufficient basis for safe conclusions, but it seems probable that this method will have to be confined to the growers who have unusually large and well-ventilated storehouses and who are able to dispose of their crops fairly early in the season.

During the season of 1920 an attempt was made to determine the length of time during which cranberries may safely be submerged before picking. Unfortunately, these tests were delayed until the very last of September, when the water was cold, and the results were inconclusive.

SUMMARY.

Investigations carried on through three seasons in Wisconsin indicate that ventilation is of great importance in the storage of water-raked cranberries, as of cranberries harvested in other ways.

Green berries are more easily injured in water-raking than ripe (fully colored) berries.

Cool water and water having a high oxygen content are much less likely to cause injury in water-raking than warm water or that having a low oxygen content.

Water used in flooding Wisconsin cranberry marshes varies considerably in oxygen content.

The oxygen content of water in reservoirs and on the flooding sections of marshes increases during clear days and decreases at night.

Under the most favorable conditions the writers have been able to obtain, the keeping quality of water-raked cranberries was somewhat inferior to that of dry-raked berries from the same sections and about equal to hand-picked berries.

Berries which are permitted to remain wet for some time after water-raking show decidedly poorer keeping quality than those quickly dried and are, of course, inferior to those which are hand-picked or dry-raked.

PRACTICAL SUGGESTIONS.

Whether berries shall be water-raked, dry-raked, or hand-picked must be decided by each grower and for each marsh separately, after taking into consideration the cost of the various methods, the available labor, the kind and quantity of water available, and especially his experience with the marsh as regards the keeping quality of the fruit produced.

If water-raking is undertaken, the berries should be under water as short a time as possible, should be well colored when harvested, and should be dried as promptly as possible.

Small flooding sections are a distinct advantage in water-raking, as the berries under such conditions need be submerged for only a short time.

The cooler the flooding water, the better the chance of successful water-raking. Clear spring or brook water is preferable to dark-colored swamp water.

Intelligent and conscientious assistants to care for the drying of the berries are absolutely necessary if water-raking is to be successfully practiced.

In packing water-raked cranberries any lots which have dried slowly because of unfavorable weather or other conditions should be kept separate and marked or sold separately.

Because of the variation in keeping quality of water-raked cranberries due to the conditions under which they are handled, it is doubtful whether water-raked berries should ever be mixed with or included with dry-raked or hand-picked berries.

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